MIDWEST SUBREGIONAL MODELING: 1-HOUR ATTAINMENT DEMONSTRATION FOR LAKE MICHIGAN AREA

SUMMARY

Illinois Environmental Protection Agency
Indiana Department of Environmental Management
Michigan Department of Environmental Quality
Wisconsin Department of Natural Resources

September 27, 2000

September 18, 2000

The purpose of this document is to summarize the updated 1-hour ozone attainment demonstration for the Lake Michigan area. The attainment demonstration is based on a state-of-the-art photochemical modeling analysis plus supplemental weight-of-evidence information (i.e., air quality data analysis). The final attainment strategy consists of four sets of controls: (1) Federal Clean Air Act controls, (2) State rate-of-progress emission reductions, (3) the Federal Tier II/Low S program, and (4) a range of regional point source NOx controls. The modeling shows that these controls provide for attainment of the 1-hour NAAQS throughout the Lake Michigan area.

Overview of Modeling: The Urban Airshed Model, version 1.24 (UAM-V) was used for the analysis. The modeling domain, which is shown in Figure 1, includes the areas of high ozone concentrations around Lake Michigan (the purple shaded area in the figure) and possible upwind source areas impacting these high concentration areas. Grid resolution was 12 m for most model runs and 4 km for a few runs.

Four episodes were modeled: June 22 - 28, 1991; July 14 - 21, 1991; June 13 - 15, 1995; and July 7 - 18, 1995. These episodes were selected because they are representative of high ozone episodes in the Lake Michigan area.

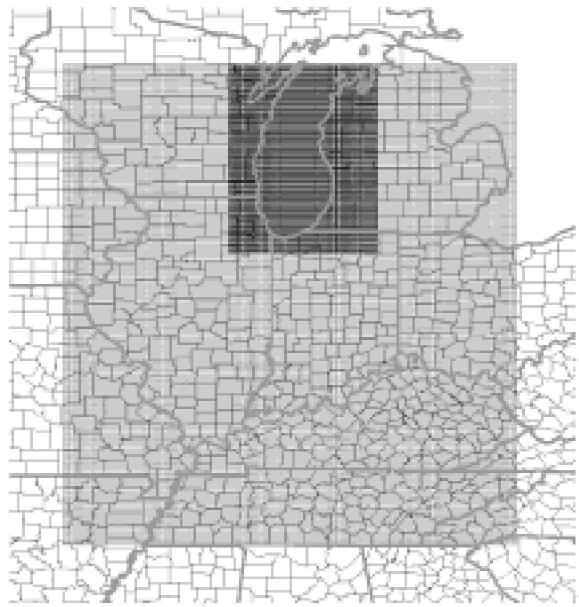

Figure 1. Map of Ozone Modeling Domain

There are three key model inputs: emissions, meteorology, and boundary conditions. The development of these inputs for the current model basecase is discussed briefly here.

Emissions: UAM-V requires a regional inventory of gridded, hourly emissions estimates for speciated volatile organic compounds (VOC), oxides of nitrogen (NOx), and carbon monoxide (CO). The emissions were processes with the EMS-95 emissions model. Emissions inventories were prepared for a 1996 base year, a 2007 base year, and several 2007 strategy/sensitivity scenarios. The inventories include 1996 state periodic inventory data for point and area sources, updated state transportation data, and updated growth and control data. Temperatures from the RAMS3a meteorological modeling were used in the calculation of motor vehicle and biogenic emissions. Biogenic emissions were based on USEPA's BEIS2 model, with an adjustment of the isoprene emissions in the Ozarks based on the OZIE field data.

Meteorology: UAM-V requires 3-dimensional hourly values of winds, temperatures, pressure, water vapor, vertical diffusivity, clouds, and precipitation. Most meteorological inputs were developed through prognostic modeling with RAMS3a. Cloud and precipitation fields were developed based on National Weather Service observations. Preliminary evaluation of the meteorological model results showed adequate representation of the general airflow features, and good agreement between modeled and measured wind speeds, temperatures, and water vapor. These findings suggest that the model results are reasonable and can be used to provide meteorological inputs for UAM-V.

Boundary Conditions: Boundary conditions were developed by applying UAM-V over the eastern half of the U.S. at 36 km grid resolution and extracting the concentration values in the grid cells that are along the edges of Grid M.

Basecase Modeling: The purpose of basecase modeling is to evaluate model performance by comparing observed and modeled concentrations. The model performance evaluation considered the spatial pattern, temporal profile, and magnitude of modeled and measured 1-hour ozone concentrations.

Peak daily 1-hour modeled and observed ozone concentrations for a representative high ozone day (July 12, 1995) are shown in Figure 2.

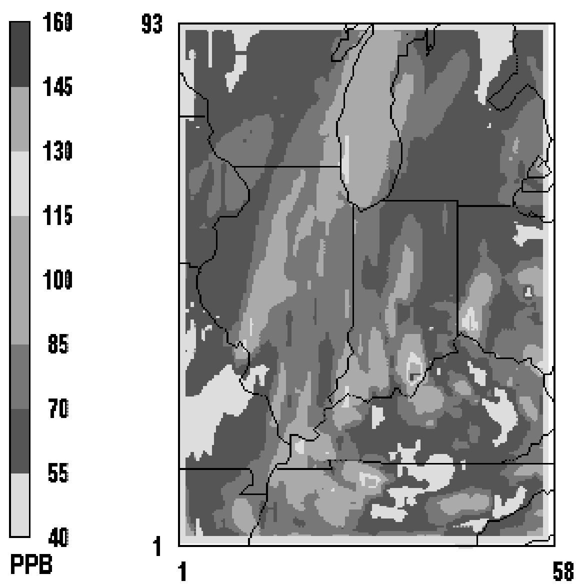

Figure 2. Predicted Ozone Concentrations (left) v. Observed (right) (July 12, 1995)

The areas of high modeled ozone concentrations correspond with the areas of high measured ozone concentrations (e.g., over Lake Michigan). Also, the regional (rural) modeled and measured ozone concentrations are comparable (i.e., on the order of 70 - 100 ppb). Peak ozone concentrations over Lake Michigan appear to be underestimated on this and many other days.

Time series plots of 1-hour modeled and observed ozone concentrations for a high ozone site in northeastern Illinois for the July 1995 episode is provided in Figure 3.

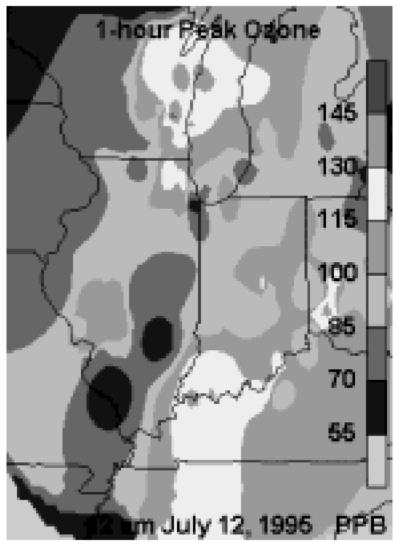

Figure 3. Time Series Plot of Modeled (line) and Observed (boxes) Ozone Concentrations

The hour-to-hour and day-to-day variation of modeled and measured ozone concentrations are comparable, with some overestimation of nighttime concentrations and some underestimation of peak afternoon concentrations.

Ozone statistics (unpaired peak accuracy, average accuracy of peak, normalized bias, and normalized gross error) are presented in Table 1. The results for the Lake Michigan area generally comply with USEPA's criteria and further indicate the tendency of the model to underestimate measured ozone concentrations. USEPA recommended that the attainment tests be applied to those days with the best model performance. Based on the results in Table 1, the following 18 days were determined to be appropriate for applying the attainment tests:

June 25, 1991	July 16, 1991	June 21, 1995	July 12, 1995
June 26, 1991	July 17, 1991	June 22, 1995	July 13, 1995
June 27, 1991	July 18, 1991	June 23, 1995	July 14, 1995
June 28, 1991	July 19, 1991	June 24, 1995	July 15, 1995
	July 20, 1991	June 25, 1995	

In summary, it is reasonable to conclude that model performance is acceptable and that the model can be used for regulatory application in the Lake Michigan area. Given the model's tendency to underestimate peak concentrations, however, it should be understood that the modeled attainment demonstration provides no margin of safety.

Table 1. Model Performance Statistics - Lake Michigan Area (12 km)

	Peak Value obs	Peak Value mod	Unpaired Peak Acc	Ave Acc of Peak	Normalized Bias	Normalized Gross Error
Jun24	92	101	9.8	-20.4	-22.6	23.6
Jun25	104	123	18.3	-16.8	-19.3	22.9
Jun26	175	136	-22.3	11.9	0.5	22.2
Jun27	118	139	17.8	10.8	4.3	17.7
Jun28	138	124	-10.1	- 5.3	-12.1	19.0
Jul16	130	129	- 0.8		-15.9	19.0
Jul17	137	119	-13.1		-16.8	20.5
Jul18	170	137	-19.4		- 2.8	15.9
Jul19	170	137	-19.4		- 9.6	20.8
Jul20	139	168	20.9		11.7	20.8
Jul21	101	142	40.6		18.3	27.9
Jun15	125	83	-33.6	-30.4	-33.6	33.7
Jun16	124	97	-21.8	-30.2	-31.9	32
Jun17	145	110	-24.1	-27.7	-29.0	29.3
Jun18	131	109	-16.8	-16.0	-18.9	20.1
Jun19	118	115	- 2.5	-14.6	-18.0	19.5
Jun20	97	120	23.7	- 8.2	-18.9	21.4
Jun21	112	123	9.8	-21.2	-23.2	25.9
Jun22	119	131	10.1	- 1.7	2.3	16.1
Jun23	123	128	4.1	-11.2	- 6.7	17.9
Jun24	166	136	-18.1	- 5.0	- 1.6	17.1
Jun25	108	125	15.7	14.4	8.3	16.3
Jul9	122	78	-36.1		-33.3	33.3
Jul10	106	88	-17.0		-30.6	30.6
Jul11	118	88	-25.4		-29.5	29.8
Jul12	146	118	-19.2		-15.2	19.2
Jul13	178	147	-17.4		-14.6	18.9
Jul14	150	140	- 6.7		- 4.3	14.6
Jul15	154	156	1.3		15.4	22.6
Jul16	92	135	46.7		23.1	25.9
Jul17	88	91	3.4		-33.2	33.3
Jul18	68	55	-19.1		-41.3	41.3
USEPA Criteria =			**15 - 20%**		**5 - 15%**	**30 - 35%**

(Note: days/values with the best model performance and which were determined to be appropriate for applying the attainment tests are identified in red above)

Strategy Modeling: The purpose of strategy modeling is to evaluate the ozone air quality impact of various control scenarios. For this modeling analysis, the following strategies were modeled:

SR1 CAA controls
SR8[1] CAA controls + 0.25 utilities (IL,IN,WI) + 0.25 utilities (KY,MO,TN) + Tier II/Low S
SR9 CAA controls + 0.20 utilities (IL,IN,WI) + 0.25 utilities (KY,MO,TN) + Tier II/Low S
SR10 CAA controls + 0.20 utilities (IL,IN,WI) + 0.25 utilities (KY,MO,TN) + SIP Call non-utilities (IL,IN,WI) + Tier II/Low S
SR11 CAA controls + 0.15 utilities (IL,IN,WI) + 0.25 utilities (KY,MO,TN) + SIP Call non-utilities (IL,IN,WI) + Tier II/Low S
SR12 CAA controls + 0.15 utilities + SIP Call non-utilities+ Tier II/Low S

SR13 SR8 w/ some changes[2]
SR14 SR12 w/ some changes[2]

SR15 SR8 w/ some new changes[3]
SR16 SR12 w/ some new changes[3]
SR17 SR12 w/ some new changes[3]

The strategy runs assumed CAA boundary conditions unless otherwise noted (i.e., sources outside of the Grid M modeling domain reflect only CAA controls). The following sensitivity runs were also modeled:

SR1a CAA controls + Tier II/Low S
SR8a SR8 + 0.25 utilities (IA)
SR8b SR8 w/ -25% VOC (L.Michigan area)
SR12a SR12 w/ -25% utility NOx
SR12b SR12 w/ -25% VOC (L.Michigan area)

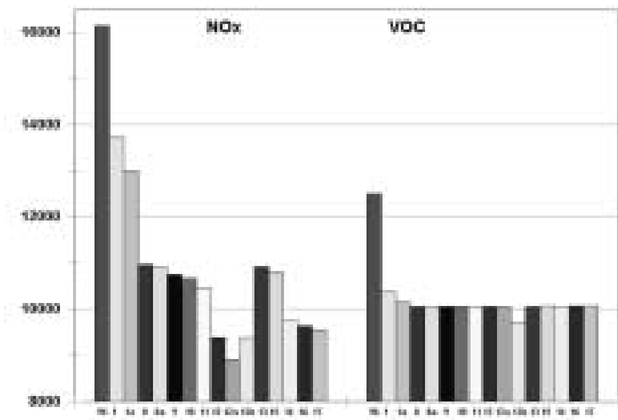

Figure 4. Domainwide Anthropogenic Emissions (tons per day)

The emissions for the strategy and sensitivity scenarios are shown in Figure 4.

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1 MI @final State rule for utilities (0.25) and non-utilities in SR8-SR11, SR13, SR15.

2 WI @ proposed State rule [0.25 utilities in 8 counties], CO credits, 13 TVA units @ 0.15, IN non-utility @ proposed State rule (SR13 only), IC engines @ CAA (SR14 only), higher VMT growth for WI, proposed diesel S rule, and updated CAA boundary conditions

3 WI @ final State rule [0.28 utilities in 8 counties], CO credits, 13 TVA units @ 0.15, IN non-utility @ proposed State rule (SR15 only), IC engines @ CAA (SR16, SR17only), MO @ SIP Call (SR17 only), higher VMT growth for WI, proposed diesel S rule, NOx I/M cutpoints in WI, corrected VMT for IL, updated MOBILE5 inputs for IL and WI, and updated CAA boundary conditions

Effect of CAA Controls:
The net effect of growth and CAA control is a reduction in VOC and NOx emissions is about 2100 tons and 2400 tons per day, respectively, compared to the 1996 base year emissions. The change in ozone concentrations due to growth and CAA controls for a high ozone day is shown in Figure 5. As can be seen, there are widespread ozone decreases and isolated increases. The ozone decreases occur in areas with high 1996 base year ozone concentrations (i.e., ozone benefits occur where it counts).

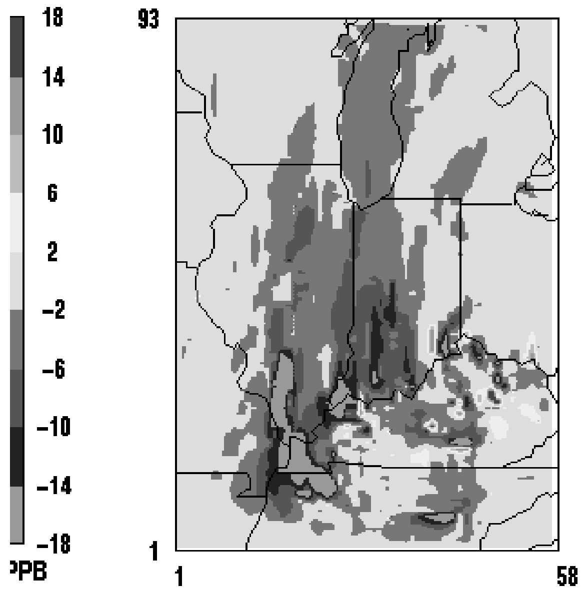
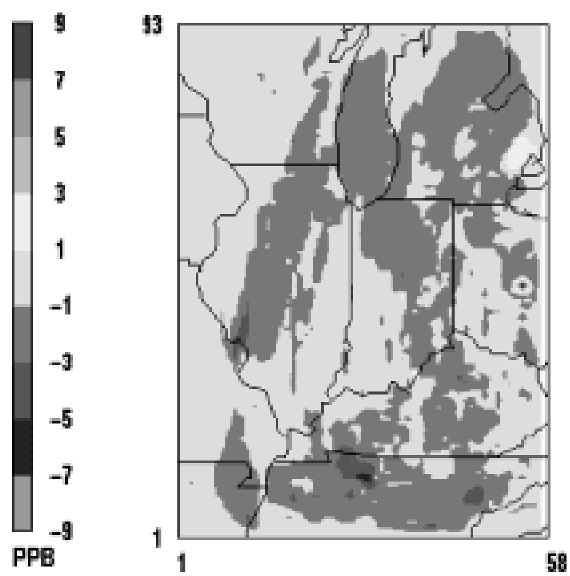


Figure 5. Change in Ozone Due to Clean Air Act Controls (July 12, 1995)

Effect of Tier II/Low S:
Tier II/Low S controls provide a reduction in VOC and NOx emissions of about 200 and 700 tons per day, respectively, compared to the Clean Air Act (SR1) control level. The change in ozone concentrations due to Tier II/Low S controls for a high ozone day is shown in Figure 6 (note that a finer concentration difference scale is used in this figure). As can be seen, there are widespread ozone decreases on the order of 1 - 3 ppb.



Figur
e 6. Change in Ozone Due to Tier II/Low S Controls (July 12, 1995)

Effect of Regional NOx Controls:
Regional utility controls (in IL, IN, MI, WI, KY, MO, and TN) reflecting 0.25 lb/MMBTU

(i.e., SR8) provide a reduction in NOx emissions of about 2000 tons per day compared to the Clean Air Act (SR1) control level. The change in ozone concentrations for a high ozone day is shown in Figure 7. As can be seen, there are some areas with ozone decreases and a few spotty areas with ozone increases.

Figure 7. Change in Ozone Due to Additional 0.25 Utility Controls (July 12, 1995)

The SIP Call controls provide a reduction in NOx emissions of about 1600 tons per day compared to the 0.25 lb/MMBTU utility control strategy (SR8). The change in ozone concentrations for a high ozone day is shown in Figure 8. As can be seen, there some areas with ozone decreases and a few spotty areas with ozone increases. Note that the ozone decreases in Figure 7 are greater than those in Figure 8 because the associated emission reductions are greater (i.e., more reduction, more benefit).

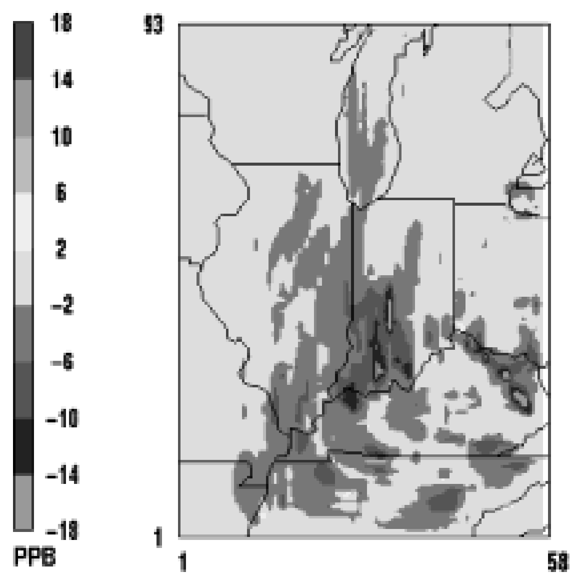


Figure 8. Change in Ozone Due to Additional SIP Call Controls (July 12, 1995)

Attainment Demonstration: USEPA's current guidance allows two attainment tests: a deterministic test and a statistical test. To supplement these tests, two additional analyses are presented: a relative attainment test and air quality data analyses (i.e., trends in ozone and ozone precursor concentrations, and application of observation-based methods).

The deterministic test is a conservative, simple means of assessing attainment. The deterministic test is passed if the daily maximum concentrations predicted in each grid cell are < 125 ppb for all days. The number of days with maximum concentrations $\geq$ 125 ppb are as follows:

SR1	SR8	SR9	SR10	SR11	SR12	SR13	SR14	SR15	SR16	SR17
8	5	5	5	5	5	4	4	5	4	4

These results show that the deterministic test is not met by any of the strategies.

The statistical approach permits occasional exceedances and reflects an approach comparable to the form of the 1-hour NAAQS. The statistical approach test is passed if three benchmarks, which are related to the frequency and magnitude of modeled exceedances and the minimum level of improvement, are met. The benchmarks are addressed below.

Benchmark 1 requires both that the number of days with modeled exceedances in each grid cell must be less than 3 and that any modeled exceedance occurs on a “severe” day. According to USEPA’s criteria, the following 10 modeling days are considered severe:

Jul 18,1991	Jun 19,1995	Jul 12,1995
Jul 19,1991	Jun 22,1995	Jul 13,1995
Jul 20,1991	Jun 24,1995	Jul 14,1995
		Jul 15,1995

The maximum number of exceedance days in any grid cell is as follows:

SR1	SR8	SR9	SR10	SR11	SR12	SR13	SR14	SR15	SR16	SR17
3	2	2	1	1	1	1	1	1	1	1

For each strategy except SR1, the modeled exceedance days all occur on severe days. For SR1, there are exceedances on two non-severe days (June 26, 1991; and June 23, 1995).

Benchmark 2 requires that the maximum modeled concentration on severe days shall not exceed 130 - 160 ppb, depending on the “severity” of the meteorological conditions. The number of days with modeled concentrations greater than the allowed value are as follows:

SR1	SR8	SR9	SR10	SR11	SR12	SR13	SR14	SR15	SR16	SR17
5	1	1	1	1	0	0	0	0	0	0

Benchmark 3 requires that the number of grid cells $\geq$ 125 ppb must be reduced by 80% on each severe day. The number of days the 80% criteria is not met are as follows:

SR1	SR8	SR9	SR10	SR11	SR12	SR13	SR14	SR15	SR16	SR17
6	0	0	0	0	0	0	0	0	0	0

These results indicate that: (1) SR1, which does not pass any of the benchmarks, is not sufficient to provide for attainment; (2) SR8 - SR11 come close to showing attainment, but appear to fall just short; and (3) SR12 - 14, which meet all three benchmarks, are sufficient to provide for attainment.

To supplement the model-based attainment tests, two additional analyses are provided:

a relative attainment test and air quality data analyses. The relative attainment test uses the observed design values in concert with modeling data (i.e., the change in ozone concentrations between the base year and a given strategy). To show attainment, the resulting model-adjusted design value must be below the ozone NAAQS. For those sites with current observed design values above the NAAQS, the resulting model-adjusted design values are as follows:

SITE	Obs. D.V.	SR1	SR8	SR13	SR14	SR15	SR16	SR17
Pleasant Prairie	**131**	**126**	116	115	114	114	113	113
Milwaukee-Bayside	**128**	123	116	115	114	114	113	113
Harrington Beach	**127**	123	113	112	111	112	110	109
Sheboygan	**125**	121	112	111	110	110	108	108
Manitowoc	**127**	121	112	111	109	110	108	108
Michigan City	**140**	**132**	**125**	124	121	122	119	119
Holland	**133**	**127**	121	120	118	119	117	117
Muskegon	**132**	**126**	120	118	117	118	117	117
Unmonitored(mid-Lake)	**140**	**132**	**126**	124	123	124	122	122

These results are consistent with those of the statistical attainment test.

Two air quality data analyses were considered: analysis of air quality trends and application of observation-based methods. The trends analysis shows that there has been considerable progress toward attainment of the 1-hour NAAQS in the Lake Michigan area. Local ozone levels have declined in recent years, but incoming ozone levels remain high. The reduction in local ozone levels can be attributed to local VOC control programs, as evidenced by the decline in ambient VOC concentrations and the VOC-limited conditions in the severe nonattainment area. To reduce regional ozone levels, the observation-based methods indicate that regional NOx controls will be effective. Thus, a strategy of additional local VOC controls and regional NOx controls is necessary to provide for attainment in the Lake Michigan area. These findings corroborate the conclusions of the modeling analysis and support the general direction of the control strategies in the modeling.

Summary: A state-of-the-art modeling analysis was performed to support the updated 1-hour ozone attainment for the Lake Michigan area. The results of the analysis are considered to be technically credible. In particular, model performance was determined to be reasonable (i.e., there is good agreement in the magnitude, spatial pattern, and temporal profile of modeled and measured ozone concentrations) and the modeled control path was found to be consistent with corroborative air quality analyses. The model can, therefore, be used to support regulatory applications for the Lake Michigan area. Several policy-relevant findings should be noted:

* Domainwide (principally, urban area) VOC emission reductions decrease ozone concentrations in urban nonattainment areas. The spatial extent of the ozone decreases is limited, but do occur in high population and

generally high ozone areas.

* Domainwide NOx emission reductions decrease ozone concentrations, but can sometimes increase ozone concentrations. Ozone decreases occur throughout much of the modeling domain, including areas with high base year concentrations. Ozone increases are limited mostly to urban areas, and are most pronounced on days with lower 1-hour concentrations.

* The modeled attainment tests show that Clean Air Act controls alone will reduce ozone concentrations, but do not, by themselves, provide for attainment of the 1-hour NAAQS everywhere in the Lake Michigan area. The full set of controls (i.e., Federal Clean Air Act controls; State rate-of-progress emission reductions; Tier II/Low S program; and a range or regional point source NOx controls, as reflected by Strategy Runs 12 - 17) provide for attainment of the 1-hour NAAQS throughout the Lake Michigan area.